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(54) **Method for cutting stone or stone-like blocks into large and thin slabs, and their reinforcement.**

(57) This invention aims to the production of new products from decorative rocks, that will be free from two serious disadvantages of the natural products, the great specific weight and the low flexural strength, also much improving the economical result of the production, because the rendering of the marble blocks-granite blocks is over the double.

The new products will be large slabs or also thin (5 ÷ 7 mm) tiles (module marble and module granite), that will be covered and reinforced on one face with substances giving them increased strengths, a decreased water absorption and a safe anchorage to the building elements.

More particularly, this invention solves mainly the problems of cutting of the decorative rocks (marbles* and granites**) into very thin slabs (5 ÷ 7 mm). The method of this invention has nothing common which that used to the productionof thin tiles, measuring 15 × 30 × 0.7 cm as it refers to the possibility of production of large and thin slabs (e.g. 155 × 320 × 0.5 cm).

* marbles are crystalline or granular compact rocks, consisting of minerals with a hardness of 3-4 of the Mosh scale (calcite, dolomite, serpentine), that can be cut, grid and polished, used as decorative and building materials.

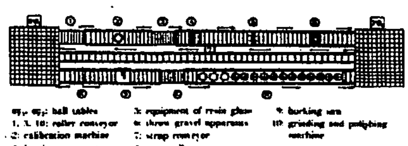
** granites are phanerocrystalline compact rocks, consisting of minerals with hardness 6-7 of the Mosh scale (quartz, feldspar, feldspathodis) that can be cut, grid and polished, used as decorative and building materials.

Furthermore, this invention solves the problem of the reinforcement of slabs with resin glass-fibers or also resin glass-clothes, which, as they are hydrophobe materials, the slabs should be completely free from dampness.

The additional increase of the inflexibility of the slabs was achieved by the use of enlarging materials (e.g. polyurethane). The self-anchorage of the slabs is realized by depositing of gravel to the still fresh surface of the resin glass-cloth.

The reinforced slabs produced within the frame of this invention are much more lighter (15-20 kg/m^2), in comparison with the natural slabs 2 cm thick (55 kg/m^2) and they can be much longer without being broken.

Finally it should be noted that each square meter of reinforced slabs is charged totally with the sum of US $ 6.00 (prices of 1986), which sum is covered by the over than the double rendering (from 1 m^3 of marble-block or granite-block the theoretical production is 40 m^2 of slabs, 2 cm thick or more than 83.3 m^2 of reinforced slabs 0.5 ÷ 0.7 cm thick).



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C O N T E N

INTRODUCTION

It is well known that the decorative natural rocks have many advantages in comparison with their antagonistic artificial products. First of all, their colour and appearance. Follow their excellent technical and physical properties, compared with the other buidling materials (concrete, ceramics etc.), their long life, as well as the possibilities to re-polish their surface (mainly of the marbles).

But, the decorative rocks present also some disadvantages as :

a) The relatively great specific weight, almost equal to that of a light metal as,for instance, aluminium.

b) The low modulus of rupture, having a negative influence on the slabs.

The low modulus of rupture is due :

i) To the natural strains sustained by the decorative rocks during the blast of the stresses on the solid crust of the Earth.

ii) To the mechanical weak points having their origin to the use of explosive material (eg. dynamite).

iii) To the fact that the decorative rocks are not subject to the plastic deformation.

And it should be certainly noted that the decorative rocks are natural materials with a high enough modulus of elasticity (450.000-1.200.000 kg/cm^2).

This invention faces both disadvantages above-mentioned, developing at the same time modern methods of cutting of marble-blocks-granite blockss into large and thin slabs and their reinforcement.

CHAPTER ONE

CUTTING OF MARBLE BLOCKS-GRANITE BLOCKS INTO THIN SLABS

The cutting of the marble blocks-granite blocks into long slabs (3,20 m) and thin slabs (5÷7 mm) is made with specially arranged frame saw machines and multidisc blocktailor machines. This is an originality having nothing to do with the existing technique of production of small tiles measuring 15 x 30 x 0,7 cm.

1. Sawing with a frame machine

For the application of the new sawing method, the marble blocks-granite blocks should be orthogonal and they should be of dimensions fully evaluating the productive possibility of the frame machine.

The dimensions of the block sawed were 3,30 x 1,85 x 1,65 ≈10 m^3, its weight was 27,10 tons and its type was that of the green cipollinic marble of Eubea isl.

The frame machine used for the experiments was a modern frame machine with a great linear velocity (≈ 2,5 m/min(, but with the following construction differentiations-modifications :

a) To the blades-bearer, diamond blades are placed, of a length greater than the normal one (5,00 m. instead of 4,20 m., which are the longest), bearing 55 instead of 42 diamond tiles (teeth), so that the great course of the blade-bearer might be fully evaluated

b) The base of the truck on which the marble blocks-granite blocks are loaded is not fixed, as usually, but it can be moved horizontally. These movements are controlled by a digital micrometer.

c) The downward speed (calata) may be controlled on the basis of the hardness of the decorative rock, so as to achieve a vertical saw and to obtain slabs of equal thickness. The descentional movement of the blade bearer is registered in a recording apparatus.

1.1. Description of the Sawing

The block was sawed into slabs 25 mm thick. The sawing stopped a few centimeters before the lower level (base) of the block. Then, the truck with the sawed block was taken away from the frame machine and the previous sawings were filled with polyurethane. The block is put again in the frame machine and is cut again. The new sawings are at an equal distance from the previous ones (those filled with polyurethane) they advance and they go out from the lower level of the block. (Fig. 1).

1.2. Rendering of the method

In this way and given that the thickness of the blade is 5,5 cm., sixty-eight (68) couples of slabs are produced, with polyurethane among them, of a current length of 3,3 m., each of a width of 1,65 m., equal to that of the block and thick 7 mm.

The commercially exploitable dimensions of each slab are 3,20 m x 1,55 m x 0,007 m. or of an area of 4,96 m^2. The total area of the 136 slabs issued by the sawing of the above block are 670 m^2. Thus, the rendering of each cubic meter is 67 square meters of final product.

The optimum downward speed of the blade bearer for the cipollinic marble is 18 cm/h. Thus, the cutting time is 165 cm/16 cm = 10 hours. Consequently, for the double sawing of the block the time necessary is 2 x 10h = 20 hours.

To the above time, other times should be added, each of about two hours, consumed, the first for the entrance and exit of the blades from the block and the second for the charging and discharging and the transfer of the block. So, within 24 hours (one day) a block of 10 m^3 is double-sawed and 670 m^2 of slabs are produced, 3,20 m. long, 1,55 m. large and 7 mm thick.

2. Cutting by a block-tailor machine

For this new cutting method, the marble blocks-granite blocks should be orthogonal and they should be of dimensions fully evaluating the productive possibility of the block-tailor machine.

The dimensions of the block cut were 3,30 x 1,20 x 1,35 = 5,35 m^3, its weight was 14,10 tons and its type that of the green cipollinic marble of Eubea island.

The block tailor machine used for the experiments was one of a great linear velocity (1,20 m/min on going and 5 m/min on return), but with the following construction differenciations-modifications :

a) To the disc-bearer twenty (20) vertical discs of 1600 mm in diameter and one horizontal disc of 450 mm in diameter are placed.

b) The dipping of the disc into the marble block-granite block is made progressively and cutting depth varies depending on the nature and the hardness of the decorative rock (4-5mm to the granites with low contents in quarz, 5-6 cm to the hard and 7-8 cm to the soft marbles for each full cycle of the discs-bearer.

c) The vertical movements of the discs-bearer and the cutting width of the linear tiles are controlled with digital micrometers.

2.1. Description of the cutting

The cutting procedure starts with the horizontalization of the upper face of the first series, with the horizontal disc. Then the vertical discs start cutting.

The block is cut into 28 mm thick linear tiles. The cutting stops when the vertical discs, 1600 mm in diameter reach the 63 cm, from the horizontal surface that was formed by the horizontal disc.

Subsequently, the truck with the block is eliminated from the block tailor machine and the cuts of the first level are filled with polyurethane. The block then is put again into the block tailor machine and is cut again. The new cuts are at an equal distance from the previous ones (those filled with polyurethane), as shown in Fig. 2.

The cycle of the cutting is ended with the new operation of the horizontal disc at a distance of 63 cm from the upper horizontal face.

In order to cut this block, two series of cuttings should be made in each level. That is, a total number of four series of cutting in the two levels.

2.2. Rendering of the method

In this way and given that the thickness of the disc is 7 mm., eighty (80) couples of lineral tiles are produced, with polyurethane among them, of 3,30 m. in length, 63 cm in width and 7 mm. thick each.

The commercially exploitable dimensions of each tile are 3,20 x 0,63 x 0,007 m. or of an area of 1,41 m^2. The total area of the 160 tiles issued by the cutting of the above block are 225 m^2. Thus, the rendering of each cubic meter is about 42 square meters of final product.

The optimum downward speed of the discs-bearer for the cipollinic marble is 4 cm (3 cm on goind and 1 cm. on return) in 3,5'. Consequently, in order to cut the first series of the first level, sixteen (16) retrograde movements (63 cm : 4 cm.) will be necessary. Thus, the cutting time for each series will be 16 x 3,5 min. = 56 min.

For the two series of the first level, the cutting time is 2 x 56 min ≈ 120 min. But, as each series is double-cutted, the full cutting time of each series reaches the 2 x 120 min= 210 min. To that time, on should add 60 min for the operation of the horizontal disc.

Consequently, the total cutting time of each level reaches 300 min or 5 hours, and so, the cutting time for both levels reaches the 10 hours.

Two more times should be added to the above time, one hour each. The first is consumed for the horizontalization of the upper face of the block and the second for the entrance and exit of the block from the block-tailor machine.

As a conclusion, within 12 hours, a block of 5,35 m^3 is cut, and 225 m^2 of tiles, measuring 3,20m x 0,63 m x 0,007 m are produced.

This rendering, refering to a 24 hours operation of the block-tailor machine, reaches, theoretically 450 m^2 of tiles, 3,20 m long, 63 cm. wide and 7 cm. thick.

CHAPTFR TWO

RFINFORCEMFNT OF THE SLABS. THEORFTICAL AND FXPERIMENTAL DATA

As above-mentioned, the problem with the long and thin slabs lies to the low flexural strength, in comparison with the metals, that becomes even lower, by the existing natural defects of the decorative rocks.

While the flexural strength of the decorative rocks rarely exceeds the 300 kg/cm^2, the max. stress developped to the thin slabs, under the influence of their own weight, is, as we are going to prove hereinafter, greater than 300 kg/cm^2, Consequenty, it is clear that the natural slabs cannot resist alone and thence they need to be reinforced.

Let it be a slab of decorative rock, with length l, width b and thickness h, that is based on its two edges (Fig, 3).

Under the influence of its own weight, a moment M is created, given by the formula $M = 1/8\ Bl^2$.

The max. stress σ is calculated by the formula :

$$\sigma = \frac{M}{I} \cdot \psi\,(1), \text{where } I = \frac{b \cdot h^3}{12} \text{ and } \psi = \frac{h}{2}$$

$$\text{or } \sigma = \frac{M \cdot \frac{h}{2}}{\frac{b \cdot h^3}{12}} = \frac{M \cdot 6}{b \cdot h^2}, \text{then } \sigma = \frac{M \cdot 6}{b \cdot h^2}$$

1. Max. stresses of the natural slabs

On the basis of the above consideration, the developped max. stresses in natural slabs 5 and 7 m thick, calculated under the influence of their own weight (volumetric weight of marble $\varepsilon_o = 2710\ kg/m^3$).

1.1. Slab measuring $l = 320$ cm, $b = 155$ cm, $h = 0,5$ cm.

The total weight of the marble slab is 67,21 kg, while the equally distributed weight B_1 is 21 kg/m.

We then have :

$$M_1 = \frac{1}{8} \cdot B_1 \cdot l^2 = \frac{1}{8} \cdot 21\ kg/cm \cdot (3{,}20m)^2 = 26{,}88\ kgm.$$

$$\sigma_1 = \frac{6 \cdot 26{,}88 kgm}{155cm \cdot (0{,}5cm)^2} = 416{,}2\ kg/cm^2 \quad \sigma_1 = 416{,}2\ kg/cm^2$$

1.2. Slab measuring $l = 320$ cm, $b = 155$ cm, $h = 0,7$ cm.

The total weight of the marble slab is 94,09 kg. The equally distributed weight B_2 of the slab was calculated to be 29,4 kq/m.

We then have :

$$M_2 = \frac{1}{8} \cdot B_2 \cdot l^2 = \frac{1}{8} \cdot 29{,}4\ kg/m \cdot (3{,}20m)^2 = 37{,}63\ kgm.$$

$$\sigma_2 = \frac{6 \cdot 37{,}63 kgm}{155cm \cdot (0{,}7cm)^2} = \frac{225{,}78\ kgm}{75{,}95\ cm^3} = 297{,}3\ kg/cm^2$$

$$\sigma_2 = 297{,}3\ kg/cm^2$$

2. Flexural strengths of the natural slabs

The flexural strength is, in this case, this natural property that can have a practical meaning. So, under the influence of a lineraly concentrated load P, a moment M is exercised, which is eoual to $Pl^2/4$, where l is the lenqth of the tile.

The flexural strength R_f is calculated by the formula :

$$R_f = \frac{\frac{Pl^2}{4}}{\frac{b \cdot h^3}{12}} \quad \frac{h}{2}$$

where b is the breadth and h the thickness of the tile.

Thence $R_f = \frac{3}{2} \cdot \frac{P \cdot l}{b \cdot h^2}$ (2)

In the following are calculated, experimentally, the flexural strength of the small tiles of cipollinic marble, 5 mm thick and of white Pentelic marble, 7 mm thick (Volumetric weight of the marbles $\varepsilon_o = 2710\ kg/m^3$).

2.1. Specimen of cipollinic marble, measuring $l = 14$ cm, $b = 5,63$ cm, $h = 0,52$ cm.

The mean load of rupture of the specimen reaches the 10,51 kq. The developping moment is calculated to 0,051 kg.m. Thence, the flexural strength is :

$$R_f = \frac{3 \cdot 10{,}51 kgm \cdot 14cm}{2 \cdot 5{,}63cm \cdot (0{,}52cm)^2} = \frac{441{,}4\ kg}{3.04\ cm^2} \text{ ή } Rf_1 = 145\ kg/cm^2$$

2.2. Specimen of white Pentelic marble measuring $l = 14$ cm, $b = 7$ cm, $h = 0,7$ cm

The mean load of rupture of the specimen reached 30,98 kg. The developping moment M was calculated to 0,152 kgm.

So, the flexural strength is :

$$R_f = \frac{3 \cdot 30{,}98 kgm \cdot 14cm}{2 \cdot 7cm \cdot (0{,}7cm)^2} = \frac{1301{,}2\ kgm}{6.86\ cm^2} \text{ ή } Rf_1 = 190\ kg/cm^2$$

3. Flexural strengths" of the reinforced slabs.

For the reinforcement of the natural slabs we used two groups of materials :

a) Polyester, epoxid, phenol resins and arco-xylane

b) Resin glass-clothes as :

- MAT (casually distributed fiber-glasses)
- STUOIA)crossed equally thick fiber-glasses)
- ROVING (longitudinal unequally thick fiber glasses)

The volumetric weight ε_o and the modulus of elasticity E' of the reinforcement materials is 1450 kg/m^3 and 220.000 kq/cm^2 respectively.

The large-thin slabs used for the reinforcement and from which were taken the specimen used for the experiments had a different thickness (5 and 7 mm) and belonged to different marbles with ε_o = 2710 kq/m^3 and E = 660.000 kg/cm^2. So that one marble (green cipollinic marble of Eubea island) presents a strong schistosity, while the other(white Pentelic marble) presents only a weak folliation.

The marble specimen used for the calculation of the "flexural strengths" were tiles reinforced with resin glass-cloth. The superficial weight Bε of the glass-clothes variated within large limits from 50 to 800 gr/m^2.

As far as the term "flexural strength" is concerned, the following is to be explained : The flexural strength of the natural slabs is calculated, as known, by the formula :

$$R_f = \frac{3}{2}\frac{Pl}{b \cdot h^2}$$

This flexural strength is certainly less than the max. stress presented by the natural slabs under the influence of a max. moment $M_{max} = B \cdot l^2/8$, where B is the equally distributed weight of the slab and l the length thereof.

Examples :

a) Natural slab of cipollinic marble, 5 mm thick : $\sigma_{max} = 416{,}2$ kg/cm^2, $Rf = 145$ kg/cm^2).

b)Natural slab of white Pentelic marble, 7 mm thick : $\sigma'_{max} = 297{,}3$ kg/cm^2, $Rf' = 190$ kg/cm^2).

The above formula $R_f = \frac{3}{2}\frac{Pl}{b \cdot h^2}$ cannot apply in the case of the reinforce slabs, as after the application of a certain load (rupture load) the flexural strengths cease to be exercised to the lower surface of the decorative rock and are all transferred to the reinforcement material. That is, when the decorative rock reaches its flexural strength, the exercised loads increase, the developed moments also increase but it can, in no case be alleged that the flexural strength of the decorative rock also increases.

In the case then of the reinforced slabs, in order to have the formula $R_f = \frac{3}{2}\frac{Pl}{b \cdot h^2}$ apply, even theorectically, another thickness h' should be used, that is calculated by the formula h = h + (h$_1$ - h)·a, where h is the thickness of the decorative rock, h$_1$ the thickness of the reinforced slab and a, a coefficient issued by the ratio of the modulus of elasticity of the reinforcement material and of the decorative rock.

The values of the elasticity measures (E=220.000 kg/cm^2 and E'=660.000 kg/cm^2) taken into consideration to the calculation of the max. stress, are the theoretical averages of the modulus of elasticity of the resin glass clothes MAT (=150.000 kg/cm^2) and ROVING (=290.000 kg/cm^2) on one hand and of the principal marbles on the other hand. Here it should be made clear that the values of the moduli of elasticity of the resin glass cloth that will be produced at the stage of the industrial production, are expected to be much greater than those of the experimental stage as the resin glass clothes of the reinforced slabs can be free from the air bubbles, closed in, during the construction of the reinforced small tiles(specimen).

It is also made clear that the modulus of elasticity of the marble derives from a compression, while that of the reinforcement material derives from a flexural tension.

Finally, it should be noted that the values of the volumentric weights (ε_o= 2710 kg/m^3 and ε_o= 1450 kg/m^3) taken into consideration for the calculation of the max. stress, constitute the theoretical averages of the calcitic marbles and the various types of resin glass clothes.

Follow the calculations of the moments developed and the issued "flexural strengths" of the reinforced small tiles, about 5 and 8 mm, under the influence of a precise load.

3.1. Reinforced slabs of cipollinic marble, 0,62÷0,68 cm. thick.

3.1.1. Marble specimen reinforced with fine-woven resin glass-cloth ($B\varepsilon$=50 gr/m^2),measuring l = 14 cm, b = 5,63 cm, h_1 = 0,62 cm (h' = 0,55 cm).

The average load of rypture of the specimen was 18,03 kg and the developing moment M was calculated to 0,088 kgm.

So, the "flexural strength"is :

$$R_f = \frac{3 \cdot 18{,}03kg \cdot 14cm}{2 \cdot 5{,}63cm \cdot (0{,}55cm)^2} = \frac{757{,}3\ kg}{3{,}406\ cm^2}\ \acute{\eta}\ Rf_2 = 222{,}3\ kg/cm^2$$

The thickness h' of the reinforced marble specimen is : h' = 0,52 cm + (0,62 = 0,52)cm' 0,3 = 0,55 cm, that is a percentage increase of the strength of the order of 53%.

3.1.2. Marble specimen reinforced with resin glass-cloth, MAT ($B\varepsilon$=350gr/m^2) measuring l=14 cm b = 5,63 cm, h = 0,68 cm (h' = 0,568 cm.).

The first sign of fissures appeared to the marble specimen, when the load reached the 31,06 kg.

The moment developed in this case was calculated to 0,152 kgm while the "flexural strenth" of the reinforced marble specimen was calculated as follows :

$$R_f = \frac{3 \cdot 31{,}06kg \cdot 14cm}{2 \cdot 5{,}63cm \cdot (0{,}568cm)^2} = \frac{1304{,}5\ kgm}{3{,}633\ cm^2}\ \acute{\eta}\ Rf_3 = 359{,}1\ kg/cm^2$$

The thickness h' of the reinforced marble specimen is : h' = 0,52 cm + (0,68-0,52) cm' 0,3 = 0,568 cm, that is a percentage incerase of the strength of the order of 148%.

3.1.3. Marble specimen reinforced with resin glass cloth STUOIA ($B\varepsilon$=650 gr/m^2) measuring l = 14 cm, b=5,63 cm, h=0,68 cm (h'=0,568 cm).

The first fissure appeared on the specimen, when the load reached the 49,75 kg.

This moment M appearing in this case was calculated to be 0,244 kgm, while the "flexural strength" of the reinforced specimen, is calculated as follows :

$$R_f = \frac{3 \cdot 49{,}75kg \cdot 14cm}{2 \cdot 5{,}63cm \cdot (0{,}568cm)^2} = \frac{2089{,}4\ kgm}{3{,}633\ cm^2}\ \acute{\eta}\ Rf_4 = 575{,}1\ kg/cm^2$$

that is an increase of the strength of the order of 292%.

3.1.4. Marble specimen reinforced with resin glass-cloth ROVING ($B\varepsilon$=250 gr/m^2), measuring l=11 cm, b=5,63 cm, h=0,68 cm (h'=0,568 cm).

The first fissure appeared in specimen, when the load reached the 49,13 kg.

The moment developed in this case was calculated to 0,241 kqm, while the "flexural strength" ofthe reinforced specimen was calculated as follows :

$$R_f = \frac{3 \cdot 49.13kg \cdot 14cm}{2 \cdot 5.63cm \cdot (0.568cm)^2} = \frac{2063{,}63\ kgm}{3{,}633\ cm^2}\ \acute{\eta}\ Rf_5 = 568{,}0\ kg/cm^2$$

that is an increase of the strength of the order of 292%.

Notes

a) In cases 3.1.3. and 3.1.4., the following fissures appear to the marble specimen with loads of 60,6 kg. corresponding to a moment of 0,297 kqm and to "flexural strengths" Rf_6= 700,6 kg/cm^2, that is an increase of the strength of the order of 383%.

b) In the cases 3.1.3. and 3.1.4. the ruptures of the reinforced marble specimen, with fragmentation of the broken zone, happens under the influence of about the same load (90,0 kg) corresponding to a moment of 0,445kgm.

Consequently, the "flexural strength" of the reinforced marble specimen Rf_7, to the limit of, rupture , reaches the 1050,9 kg/cm^2, that is an increase of theorder of 625%.

3.2. Reinforced slabs of white Pentelic marble 0,76÷0,82 cm thick.

3.2.1. Marble specimen reinforced with fine woven resin glass cloth (Bε=50 gr/m^2) measuring l=11 cm, b=7 cm, h=0,7cm(h'=0,718 cm).

The mean load of rupture of the specimen was 44,32 kg and the developed moment M was calculated to 0,217 kgm.

Thence, the "flexural strength"is :

$$R_f = \frac{3\cdot 44{,}32kg\cdot 14cm}{2\cdot 7cm\cdot (0{,}718cm)^2} = \frac{1861{,}4\ kg}{7{,}217\ cm^2} - \acute{\eta}\ Rf_3 = 257{,}9\ kg/cm^2$$

The thickness h' of the reinforced specimen is : h'-0,70 cm + (0,76-0,70) cm·0,3 = 0,718 cm, that is increase of the strength of the order of 36%.

3.2.2. Marble specimen reinforced with resin glass-cloth MAT (Bε= 350 gr/m^2)measuring l=14 cm, b = 7 cm, h = 0,8 cm, (h = 0,73 cm).

The first fissure appeared to the specimen when the load reached the 69,70 kg.

The moment M developed in this case was calculated to be 0,341 kgm, while the"flexural strength" of the reinforced specimen was calculated as follows :

$$R_f = \frac{3\cdot 69{,}70kg\cdot 14cm}{2\cdot 7cm\cdot (0{,}73cm)^2} = \frac{2929{,}9\ kgm}{7{,}461\ cm^2}\ \acute{\eta}\ Rf_3 = 392{,}7\ kg/cm^2$$

The thickness h' of the reinforced specimen is : h'-0,70cm+(0,80-0,70)cm·0,3-0,73 cm that is an increase of the strength of the order of 107%.

3.2.3. Marble specimen reinforced with resin glass-cloth STUOIA (Bε= 850 gr/m^2) measuring l=14cm, b=7cm, h=0,82cm(h'=0,736cm).

The first fissure appeared in the specimen when the load reached the 114,46 kg.

The moment M developed in this case was calculated to be 0,561 kgm, while the "flexural strength" of the reinforced specimen was as follows :

$$R_f = \frac{3\cdot 114{,}46kg\cdot 14cm}{2\cdot 7cm\cdot (0{,}736cm)^2} = \frac{4807{,}7\ kg}{7{,}584\ cm^2}\ \acute{\eta}\ Rf_4 = 633{,}9\ kg/cm^2$$

The thickness h' of the reinforced specimen is : h'=0,70cm + (0,82−0,70)cm·0,3 = 0,736cm that is an increase of the strength of the order of 234%.

3.2.4. Marble specimen reinforced with resin glass-cloth ROVING (Bε=250 gr/m^2, measuring l = 14 cm, b = 7 cm, h = 0,8 cm (h' = 0,73 cm).

The first fissure appeared to the specimen when the load reached the 110,3 kg.

This moment M' developed in this case was calculated to 0,540 kgm, while the "flexural strength" of the reinforced specimen is calculated as follows :

$$Rf = \frac{3\cdot 110{,}3kg\cdot 14cm}{2\cdot 7cm\cdot (0{,}73cm)^2} = \frac{4632{,}3\ kg}{7{,}461\ cm^2}\ \acute{\eta}\ Rf_5 = 620{,}9\ kg/cm^2$$

that is an increase of the strength of 227%.

NOTES

a) In the cases 3.2.3 and 3.2.4., the following fissures appear to the marble specimen with loads of 139,5 kg and 130,15 kg corresponding to moments of 0,684. kg and 0,638 kg and to "flexural strengths" $Rf_6 = 732{,}6\ kg/cm^2$, και $Rf_6 = 772{,}5\ kg/cm^2$, i.e.increases of strength of the order of 307% and 286%.

b) In cases 3.2.3. and 3.2.4., the ruptures of the reinforced marble specimen, with fragmentation of the broken zone, happens under the influence of about the same load that corresponds to a moment of 0,779 kgm and in "flexural strengths" $Rf_7 = 881{,}1\ kg/cm^2$ and $\bar{R}f_7 = 895{,}6\ kg/cm^2$, that is increases of the strengths of the order of 364% and 371%.

4. Calculation of the modulus of elasticity of the resin glass-clothes

In para 3 it was accepted that the modulus of elasticity E of the reinforcement material (resin glass cloth) is 220.000 kg/cm^2. But, as the modulus of elasticity of the reinforcement material varies, depending on the type of the glass-cloth, hereinunder is specified experimentally the modulus of elasticity E (ratio of stress σ to strain ε) for every case separately, on the basis of the results of the experiments realized, in specimen specially made to this end.

4.1. Resin glass-cloth MAT 350

From measurements effected in the diagram of fig. 4, it was calculated that the $\sigma = 21,5\ kg/cm^2$ and the $\varepsilon = 138 \cdot 10^{6}$.

Thence the $E = \dfrac{21,5\ kg/cm^2}{138 \cdot 10^{-6}}$ ή $E = 155.797\ kg/cm^2$.

4.2. Resin glass-cloth STUOIA 850

From measurements effected in the diagram of fig. 5, it was calculated $\sigma = 27,8 kg/cm^2$ and $\varepsilon = 90 \cdot 10^{6}$.

Thence $E = \dfrac{27,8\ kg/cm^2}{90 \cdot 10^{-6}}$ ή $E = 308.889\ kg/cm^2$

4.3. Resin glass-cloth ROVING 250

From measurements effected to the diagram of fig. 6, it was calculated $\sigma = 55,8\ kg/cm^2$ and $\varepsilon = 190 \cdot 10^{6}$.

Thence $E = \dfrac{55,8\ kg/cm^2}{190 \cdot 10^{-6}}$ ή $E = 293.684\ kg/cm^2$

5. Conclusions

It is true that, the results of the experiments, as these appear in the previous paragraphs, may be decisive for the application of this invention. And in the affirmative development, the same experiment data play a decisive role to the choice of the reinforcing materials and further to the calculation of the cost of the new products. Anyway, that which has a practical meaning in this case, is to be able to calculate, each time, the max. length of the reinforced long-thin slab, of h thickness, futher to which this is broken.

More precisely :

Let it be a natural long-thin slab ($\varepsilon_o = 2710\ kg/m^3$) of an l length, a b breadth and of an h thickness. Then, the weight per current centimeter will be :

$$B = 2,71 \cdot 10^{-3} \times l \times b \times h\ (kg/cm)$$

To the developing max moment $M_{max} = B \cdot l^2/8$, a max. stress corresponds as follows

$$\sigma_{max} = \frac{B\,\frac{l^2}{8}}{\frac{b \cdot h^2}{6}} = \frac{3}{4}\,\frac{Bl^2}{bh^2}$$

from which is issued the length of the slab,

$$l = \sqrt{\frac{\sigma_{max} \cdot h}{2,032 \times 10^{-3} kg/cm^3}} \qquad (1).$$

If the max stress is substituted by the flexural stength of the marble, then the formula (1) becomes :

$$l = \sqrt{\frac{R_f \cdot h}{2{,}032 \times 10^3 kg/cm^3}} \qquad (2).$$

Examples :

The natural slabs of the green cipollinic marble, 0,5 cm thick, that present a flexural strength $Rf = 145\ kg/cm^2$, give a max. length

$$l = \sqrt{\frac{145 kg/cm^2 \cdot 0{,}5 cm}{2{,}032 \cdot 10^{-3}\ kg/cm^3}} = 189 cm \text{ or } l = 189 cm$$

While the natural slabs of white Pentelic marble, 7 mm thick, presenting a flexural strength $Rf' = 190 kg/cm^2$, may be cut longer enough

$$l' = \sqrt{\frac{190 kg/cm^2 \cdot 0{,}7 cm}{2{,}032 \cdot 10^{-3}\ kg/cm^3}} = 256 cm \text{ or } l' = 256 cm$$

Concerning the reinforced slabs, the experiments showed that these can accept much greater loads and consequently increased moments, always in relation with the natural slabs.

Furthermore it is noted that measurements of the loads exercises were effected in three precise stages. The forst stage was that during which the first fissure was seen (it is a not easily seen white line that has absolutely no unfavourable influence on the use of the decorative rock). The second stage was that during which appeared more (about five) fissures (that is white lines that in no case render the decorative rock unsuitable). The third case is that of the rupture of the reinforced slab (that is the decorative rock has been fragmented and consequently is unsuitable for any use).

The moments developed during the above three stages are given the histogram of the Fig. 7.

As the ratio of the developing max. moments is equal to the ratio of the quadrants of the lengths of the slabs

$$\frac{M}{M'} = \frac{\frac{Bl^2}{8}}{\frac{Bl'^2}{8}} = \frac{l^2}{l'^2} \qquad (3),$$

where M is the moment corresponding to the stress coinciding with the flexural strength of the marble, M' is the moment corresponding to the first fissure or the "multiple" fissures, l the max. length of the natural slab and l' the sought max. length of the reinforced slab.

From the formula (3) we have

$$l' = \sqrt{\frac{M'}{M}}\, l \qquad (4)$$

Applying the formula (4) for the reinforced slabs of the green cipollinic marble and the while Pentelic marble, the gollowing table is issued :

TABLE I. Max. lengths of slabs reinforced with various glass-clothes. The security coefficient $\sigma = 1,2$, refers to the stage of the first fissure and can be considered as abs-lutely satisfactory.

	Glass-cloth type	cipollinic marble		White Pentelic marble	
		Max. length (cm)	M.m. (cm) with $\sigma=1,2$	Max. length (cm)	(cm) with $\sigma=1,2$
first fissure	Fine-woven 50	248	207	306	255
	MAT 350	326	272	383	319
	STUOIA 850	413	344	492	410
	ROVING 250	411	343	483	403
multiple fissures	STUOIA	456		543	
	ROVING			524	
fragmentation of marble	STUOIA	558		580	
	ROVING				

From the above results one can conclude that for the production of slabs longer than 3,20 m and less thick than 7 mm, these slabs, in order to resist, should be reinforced, exclusively, with resin glass-clothes STUOIA and ROVING.

Anyway, in any case it is convenient to use the ROVING 250 because this has the best behaviour and the less, except for the fine woven, superficial weight (250 gr/m^2).

Finally, concerning the bond stress of the marble slabs and the resin glass-clothes, it should be noted that an experimental determination was not possible, as in the specimen especially formed to that end, not only there was no yielding observed but on the contrary, a rupture of the specimen happened after the influence of a certain load. These experimental data offered the possibility for a calculation, in a direct way, of the flexural strengths of the green cipollinic marble and the white Pentelic marble, reaching the 35 and 48 kg/cm^2 respectively.

Remark

The bond failure initially observed in some specimen was due to the decreased bond between the reinforcement material and the marble, due to the superficial sampness of the slabs and the inadequate hardening of the resins.

CHAPTER THREE

REINFORCEMENT AND ELABORATION OF THE SLABS-PRODUCTS

The principle on which is based the reinforcement and elaboration of the slabs (frame-machine and block-tailors machine) is the same. Only the size of the machines differ and in correlation with this, their productive capacity.

But the imperative problem is the adhesion of the resin glass-cloth to the surface of the slab. Because it is known that this adhesion is sensibly decreased from the presence of dampness that has penetrated in the granules or crystals (papillary water) at the cutting of the marble blocks-granite-blocks.

1. Reinforcement and elaboration of the slabs

1.1. Elimination of dampness from the marble slabs-granite slabs.

It is clear that, the heating of the surfaces alone by electrical resistances or any other way(eg. ultrared rays) does not solve the problem. Because in these cases the elimination of the dampness takes place only superficially.

This serious impediment was gone pas in this invention, by the application of the known physical law according to which, the water evaporation (dampness) is correlated (increases) with the increase of temperature and the decrease of the atmospheric pressure.

Evaluating this second parameter, the elimination of humidity is effected in two phases. During the first phase, a group of slabs is placed into a concrete pool measuring 3,50m$\cdot$1,80m$\cdot$ 1,80m = 11,5 m^3, which is under the ground and is vaccuum clcsed by a specific resistant cover. By a vaccuum pump, the pressure is decreased in the pool from 760 to about 70 Torr.

After one hour, the dampness, under the form of capillary water, has been eliminated.

1.2. Description of the reinforcement and elaboration of the slabs

After the elimination of the dampness in the vacuum pool, the double slabs, with polyurethane among them are driven to first table ball and thence, by a roller conveyor to the heating apparatus of the upper surface of the slab with electric resistances. Immediately afterwards, the slabs are advanced to the resin plant. Then, a resin glassclothis attached to the slabs and finally, if desirable, gravel of about three ml. is thrown to the still damp surface, by a special apparatus.

The double slab with the resin glass-cloth and the gravel, to the upper surface thereof, is driven via the second table ball to the continuous belt and thence to the first table ball.

This course of more than twenty meters is enough for the heardening of the resin. By the use of the calibration machine, a total thickness of resin glass cloth and gravel of 3,5 mm is achieved.

To this point, the double slab is reversed and the previous procedure is followed, so that the other surface too be covered with resin glass-cloth and gravel.

The double slab covered in both surface with resin glass-cloth (Fig. 9) goes through a special saw belt, the polyurethane is cut and so it is separated into two slabs.

Those slabs can be standardized by the cross-cut saws and then, having been elaborated in the grinding and polishing machine from the surface which is covered with polyurethane, they are driven to the second table-ball and then packed.

The necessary equipement and the flow of the elaboration procedure for the reinforcement of the natural slabs, is given in Fig. 10.

2. Products

The products issued by the above elaboration may be characterized by the general term of Reinforced Decorative Rocks (RDR) (Fig. 11).

If gravel is attached to the reinforced decorative rocks, new products called Autoanchored RDR are issued. (Fig. 12)

To the surface of the decorative rock reinforced with resin glass-cloth, polyurethane, 3÷5 cm thick can be attached, acting on one had as an isolating material and on the other hand multiplying, by the formica sheet, the inflexibility of the decorative rock (Fig. 13).

These composite products will be sold under the name of RDR Panelling and will be produced as follows :

In the bottom of a cast having the dimensions of the great slabs (3,30x1,60 m or 3,30 x 0,63 m(and a depth of 3÷5 cm, the formica is placed. On the cover of the cast the marble slab is placed, with the residn glass cloth facing the interior of the cast. The empty space between the slab and the formica is filled with polyurethane which is enlaged and solidified within a very short period of time (eg. 20 esec.).

From the above great slabs of the two first classes of products, the following standard products can be issued :

a)Tiles measuring 30x60 cm, 40x80 cm and 50x50 cm.
b)Modulmarmo and Modulgranite measuring 25x50 cm and 30x30 cm.
c)Small tiles measuring 15x30 cm and 15x15 cm.

Finally, from the third class of products, mainly pre-constructed elements may be produced, which are used as separations for rooms and bathrooms, as covers for tables, sinks etc.

CHAPTER FOUR

ADVANTAGES OF THE NEW TECHNOLOGY PRODUCTS

As it was proved above, by this invention, the two unique disadvantages of the decorative rocks, i.e. the great specific weight and the low, in comparison with the metals, flexural strength, can be refuted.

The reinforced slabs, 6÷8 mm thick, by the new technology, present, in comparison with the natural marble slabs or granite slabs, the following considerable advantages :

a) Their weight is the half (see fig. 14) and consequently their transport cost is considerably decreased.

b) Their rendering is more than the double in square meters, per cubic meter of marble block-granite block (see Fig. 15) and thus there is a considerable decrease of the cost of the reinforced slab deriving from the raw material, while in parallel they greatly contribute to the economization of non renewable mineral resources as the marbles and the granite.

c) The allow a very great increase of the max length of the natural slabs, while at the same time, they offre a great impact resistance, so that the risk of their rupture during transport and posing is decreased to the minimum.

d) They present a minimum water absorption and excellent thermal isolation properties (mainly the RDR panelling products).

e) They attribut to the decorative rocks, the optimal possible adhesion to the building elements, so that they can be characterized as self anchored elements.

f) They contribute to the exploitation of valuable marbles mechanically deformed by natural and technical reasons.

g) They cost cheaper, as the charging of the costing prices from the reinforcement materials is covered by the over that the double rendering.

h) They offer greater profits, as they are sold at higher prices and they cost cheaper.

CLAIMS

1. Sawing with a frame machine

For the application of the new sawing method, the marble blocks-granite blocks should be orthogonal and they should be of dimensions fully evaluating the productive possibility of the frame machine.

The dimensions of the block sawed were 3,30 x 1,85 x 1,65 =10 m^3, its weight was 27,10 tons and its type was that of the green cipollinic marble of Eubea isl. (Fig. 1).

The frame machine used for the experiments was a modern frame machine with a great linear velocity (= 2,5 m/min(, but with the following construction differentiations-modifications :

a) To the blades-bearer, diamond blades are placed, of a length greater than the normal one (5,00 m. instead of 4,20 m., which are the longest), bearing 55 instead of 42 diamond tiles (teeth)*, so that the great course of the blade-bearer might be fully evaluated

b) The base of the truck on which the marble blocks-granite blocks are loaded is not fixed, as usually, but it can be moved horizontally. These movements are controlled by a digital micrometer.

c) The downward speed (calata) may be controlled on the basis of the hardness of the decorative rock, so as to achieve a vertical saw and to obtain slabs of equal thickness. The descentional movement of the blade bearer is registered in a recording apparatus.

2. Cutting by a block-tailor machine

For this new cutting method, the marble blocks-granite blocks should be orthogonal and they should be of dimensions fully evaluating the productive possibility of the block-tailor machine.

The dimensions of the block cut were 3,30 x 1,20 x 1,35 = 5,35 m^3, its weight was 14,10 tons and its type that of the green cipollinic marble of Eubea island (Fig. 2).

The block tailor machine used for the experiments was one of a great linear velocity (1,20 m/min on going and 5 m/min on return), but with the following construction differenciations-modifications :

a) To the disc-bearer twenty (20) vertical discs of 1600 mm in diameter and one horizontal disc of 450 mm in diameter are placed.

b) The dipping of the disc into the marble block-granite block is made progressively and cutting depth varies depending on the nature and the hardness of the decorative rock (4-5mm to the granites with low contents in quarz, 5-6 cm to the hard and 7-8 cm to the soft marbles for each full cycle of the discs-bearer.

c) The vertical movements of the discs-bearer and the cutting width of the linear tiles are controlled with digital micrometers.

3. Elimination of dampness from the marble slabs-granite slabs.

It is clear that, the heating of the surfaces alone by electrical resistances or any other way(eg. ultrared rays) does not solve the problem. Because in these cases the elimination of the dampness takes place only superficially.

This serious impediment was gone pas in this invention, by the application of the known physical law according to which, the water evaporation (dampness) is correlated (increases) with the increase of temperature and the decrease of the atmospheric pressure.

Evaluating this second parameter, the elimination of humidity is effected in two phases. During the first phase, a group of slabs is placed into a concrete pool measuring 3,50m·1,80m·1,80m = 11,5 m^3, which is under the ground and is vaccuum closed by a specific resistant cover. By a vaccuum pump, the pressure is decreased in the pool from 760 to about 70 Torr.

After one hour, the dampness, under the form of capillary water, has been eliminated.

*The length of the blade and the number of the teeth may vary and this docs not mean a change to the principle of operation.

4. Reinforcement and elaboration of the slabs

For the reinforcement of the natural slabs we used two groups of materials :

a) Polyester, epoxid, phenol resins and arco-xylane

b) Resin glass-clothes as :
   - MAT (casually distributed fiber-glasses)
   - STUOIA)crossed equally thick fiber-glasses)
   - ROVING (longitudinal unequally thick fiber glasses)

The volumetric weight ε_o and the modulus of elasticity E' of the reinforcement materials is 1450 kg/m^3 and 220.000 kq/cm^2 respectively.

After the elimination of the dampness in the vacuum pool, the double slabs, with polyurethane among them are driven to first table ball and thence, by a roller conveyor to the heating apparatus of the upper surface of the slab with electric resistances. Immediately afterwards, the slabs are advanced to the resin plant. Then, a resin glassčlothis attached to the slabs and finally, if desirable, gravel of about three ml. is thrown to the still damp surface, by a special apparatus.

The double slab with the resin glass-cloth and the gravel, to the upper surface thereof, is driven via the second table ball to the continuous belt and thence to the first table ball.

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The double slab covered in both surface with resin glass-cloth (Fig. 9) goes through a special saw belt, the polyurethane is cut and so it is separated into two slabs.

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The necessary equipement and the flow of the elaboration procedure* for the reinforcement of the natural slabs, is given in Fig. 10.

5. Products

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In the bottom of a cast having the dimensions of the great slabs (3,30x1,60 m or . 3,30 x 0,63 m(and a depth of 3÷5 cm, the formica is placed. On the cover of the cast the marble slab is placed, with the residn glass cloth facing the interior of the cast. The empty space between the slab and the formica is filled with polyurethane which is enlaged and solidified within a very short period of time (eg. 20 esec.).

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* It is specified that the breadth and the order of position of the machines, as well as the number of the sprayers of resin and the abrasion-polishing heads described to the above figure may vary.

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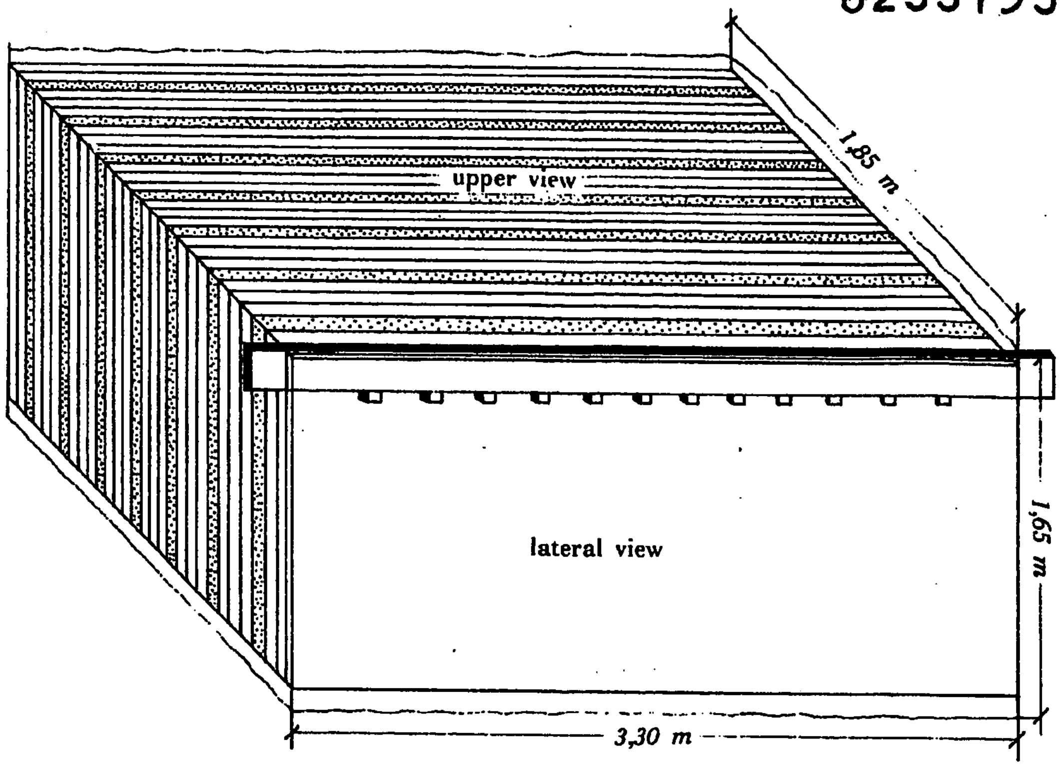


FIG. 1

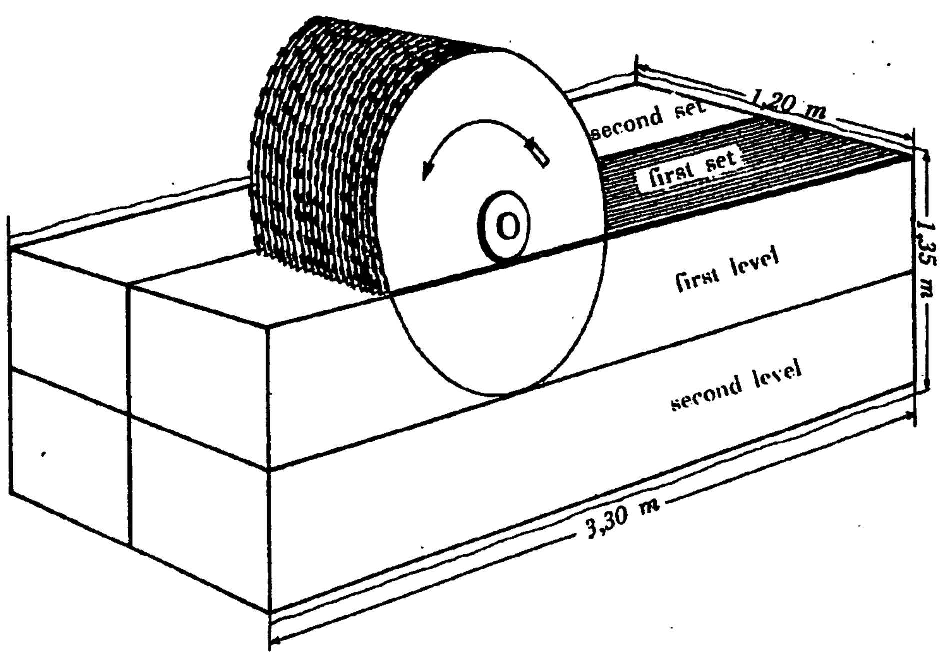


FIG. 2

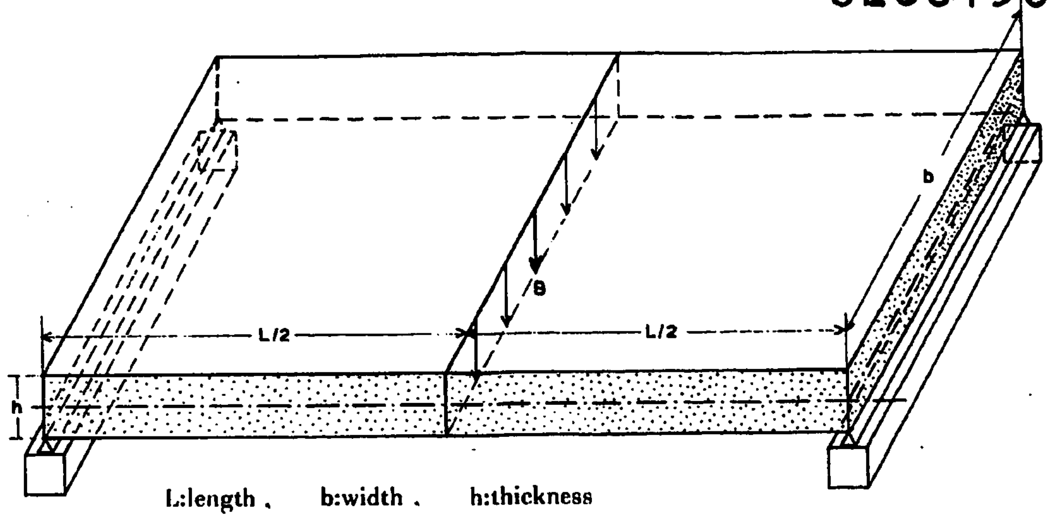

L/2
L/2
b
B
h
L:length , b:width , h:thickness

FIG. 3

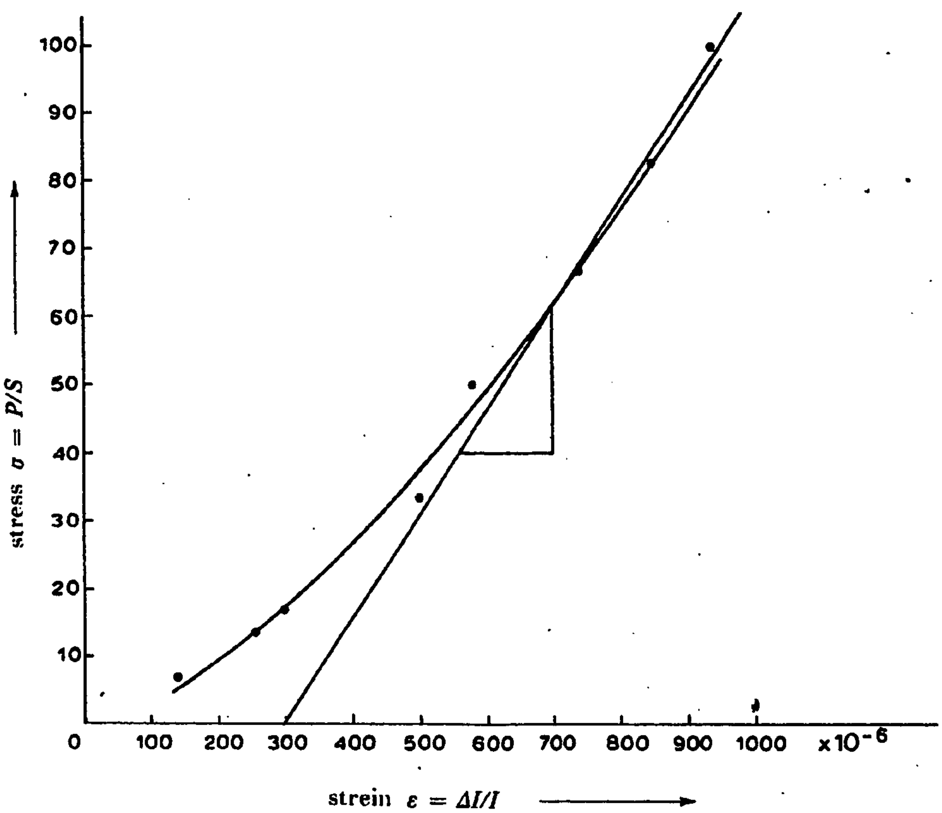

100
90
80
70
60
50
40
30
20
10
0
100
200
300
400
500
600
700
800
900
1000
x10⁻⁶
stress σ = P/S
strein ε = ΔI/I

FIG. 4

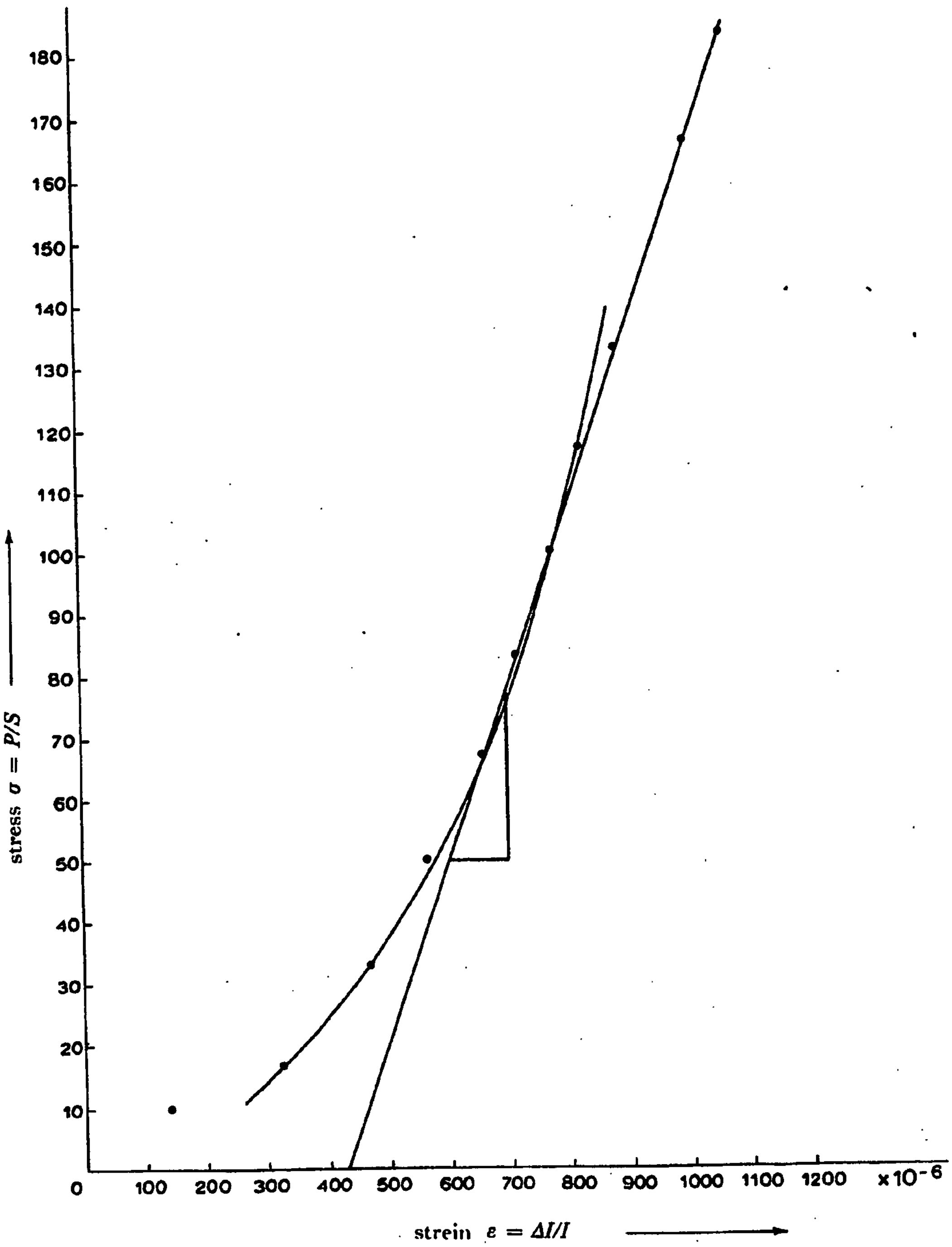

180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
x10⁻⁶
stress σ = P/S
strein ε = Δl/l

FIG. 5

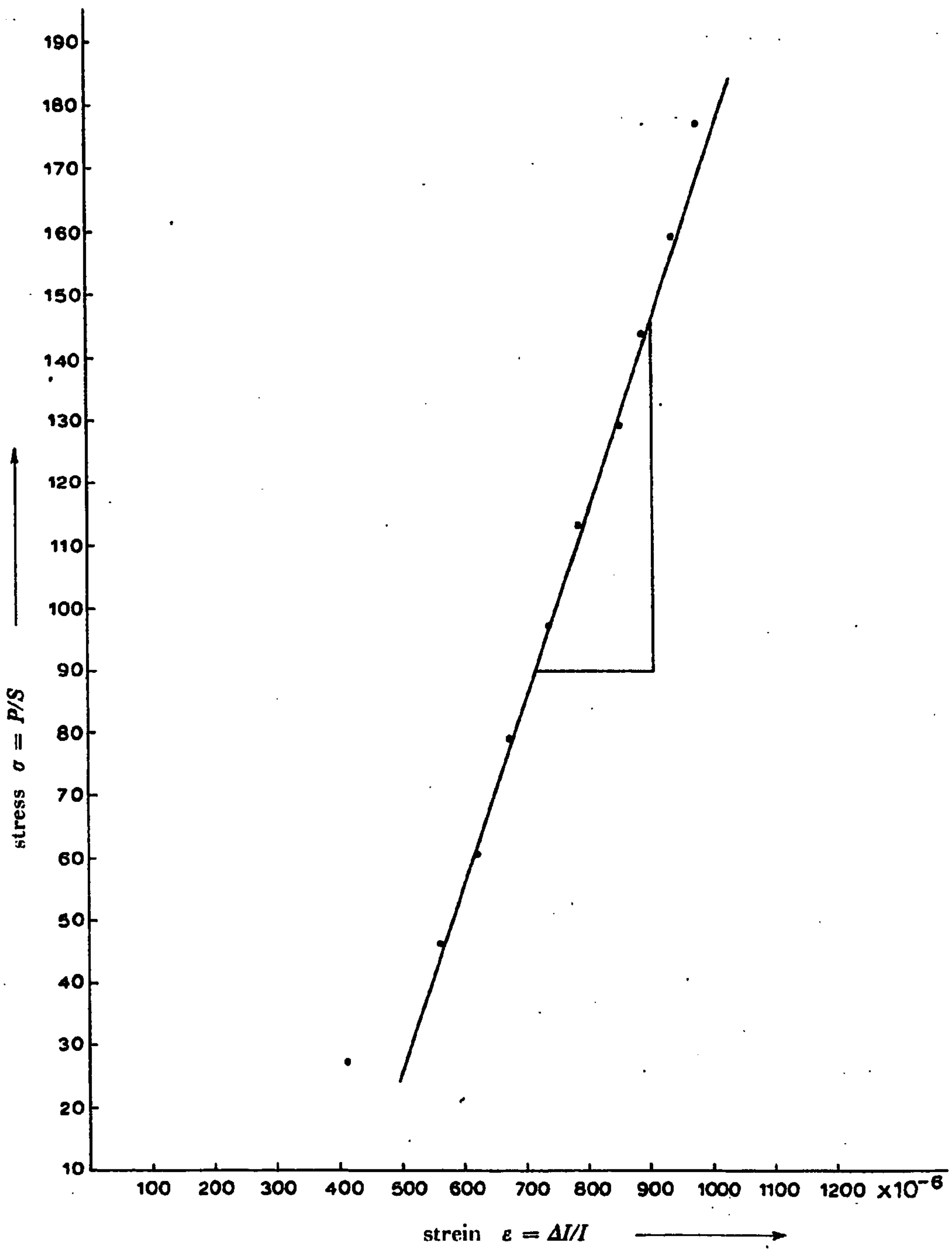
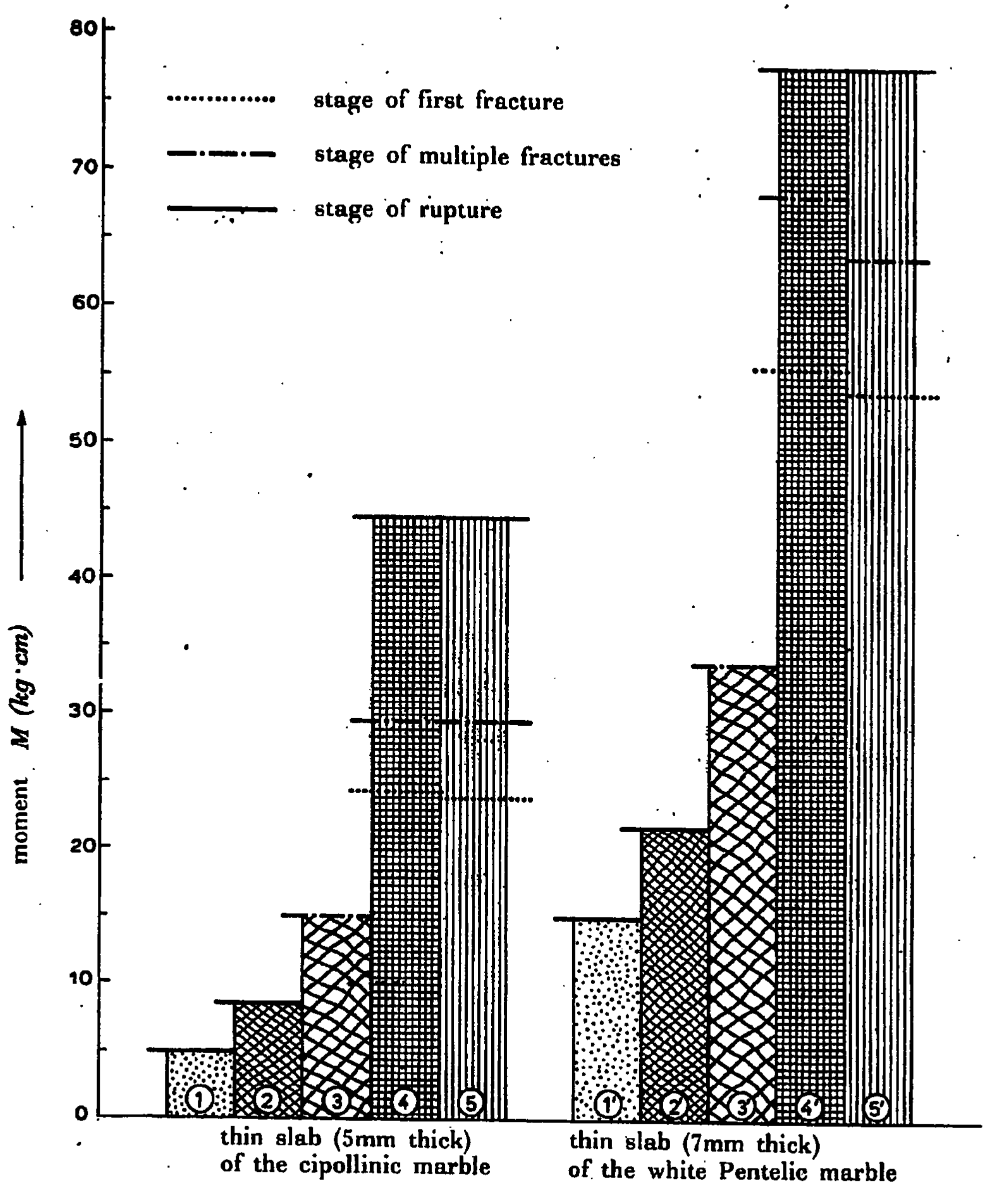

190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
stress σ = P/S
100 200 300 400 500 600 700 800 900 1000 1100 1200 x10⁻⁶
strein ε = Δl/l

FIG. 6



1: thin slab in the natural state
2: thin slab reinforced with resin glass thin-woven
3: thin slab reinforced with resin glass MAT 350
4: thin slab reinforced with resin glass STUIOA 850
5: thin slab reinforced with resin glass ROVING 250

FIG. 7

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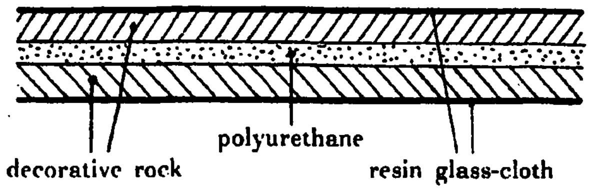
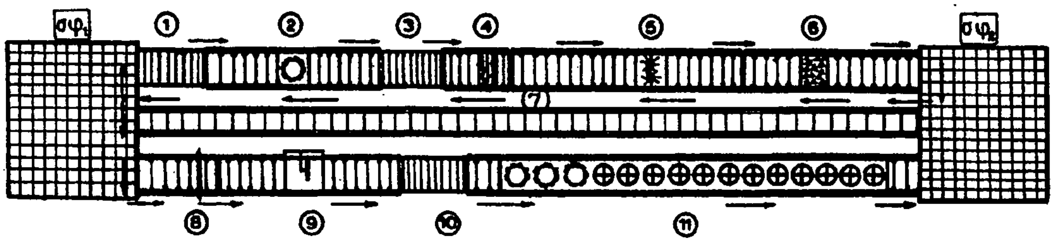


FIG. 9



$\sigma\varphi_1$, $\sigma\varphi_2$: ball tables
1, 3, 10: roller conveyor
2: calibration machine
4: heating apparants
5: equipment of resin glass
6: throw gravel apparants
7: strap conveyor
8: saw endless
9: bucking saw
10: grinding and polishing machine

FIG. 10

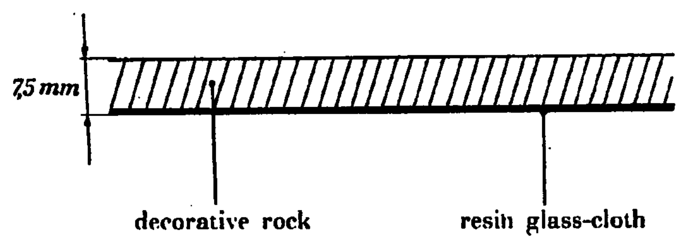


FIG. 11

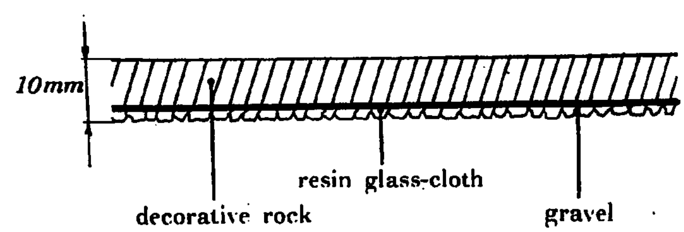


FIG. 12

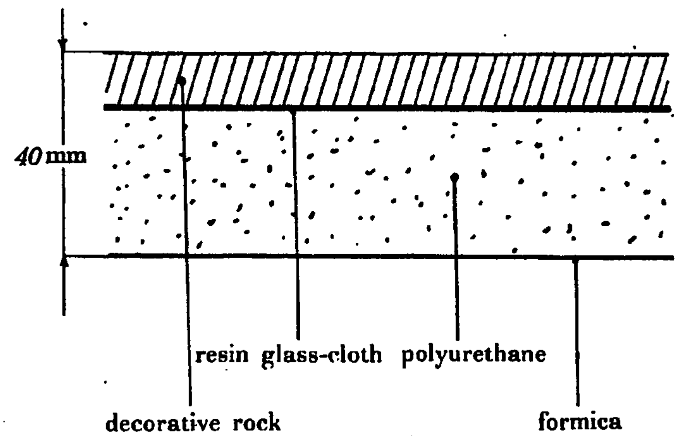

40 mm
resin glass-cloth
polyurethane
decorative rock
formica

FIG. 13

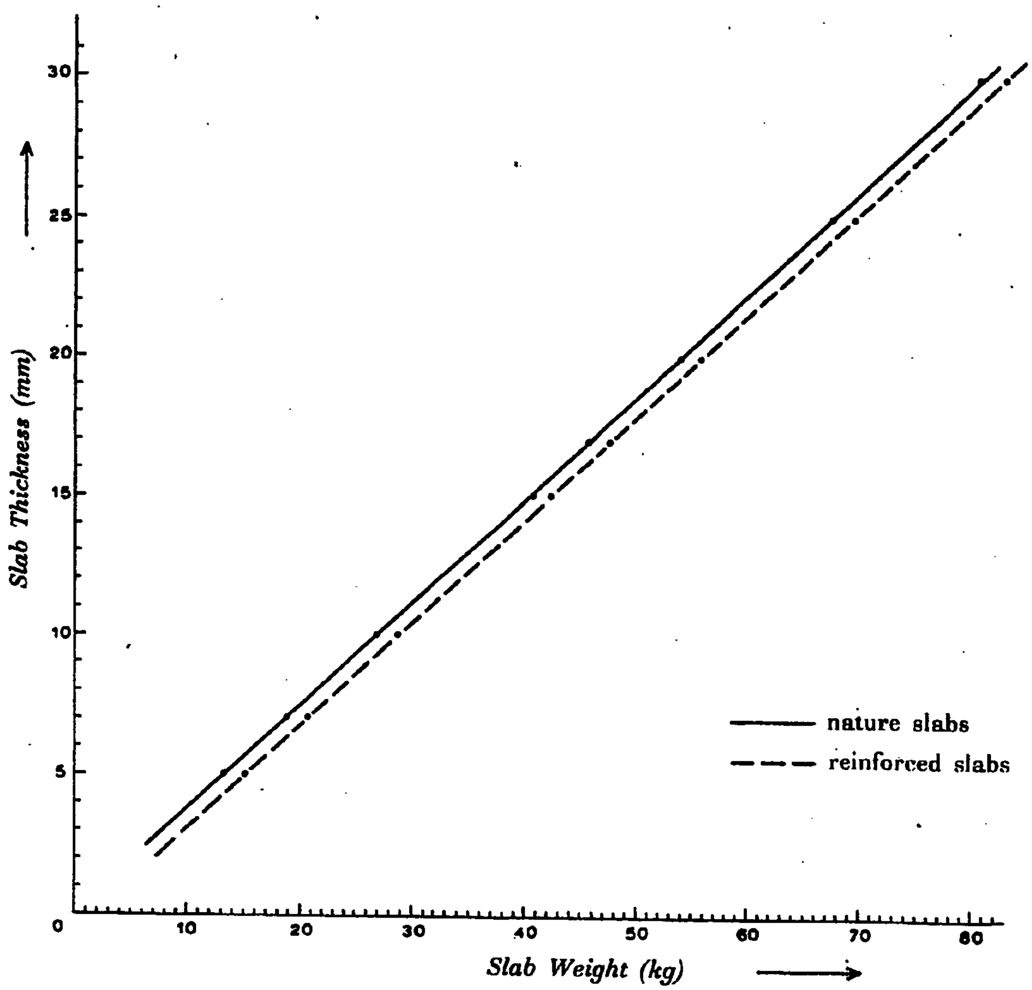

Slab Thickness (mm)
0
5
10
15
20
25
30
10
20
30
40
50
60
70
80
Slab Weight (kg)
nature slabs
reinforced slabs

FIG. 14

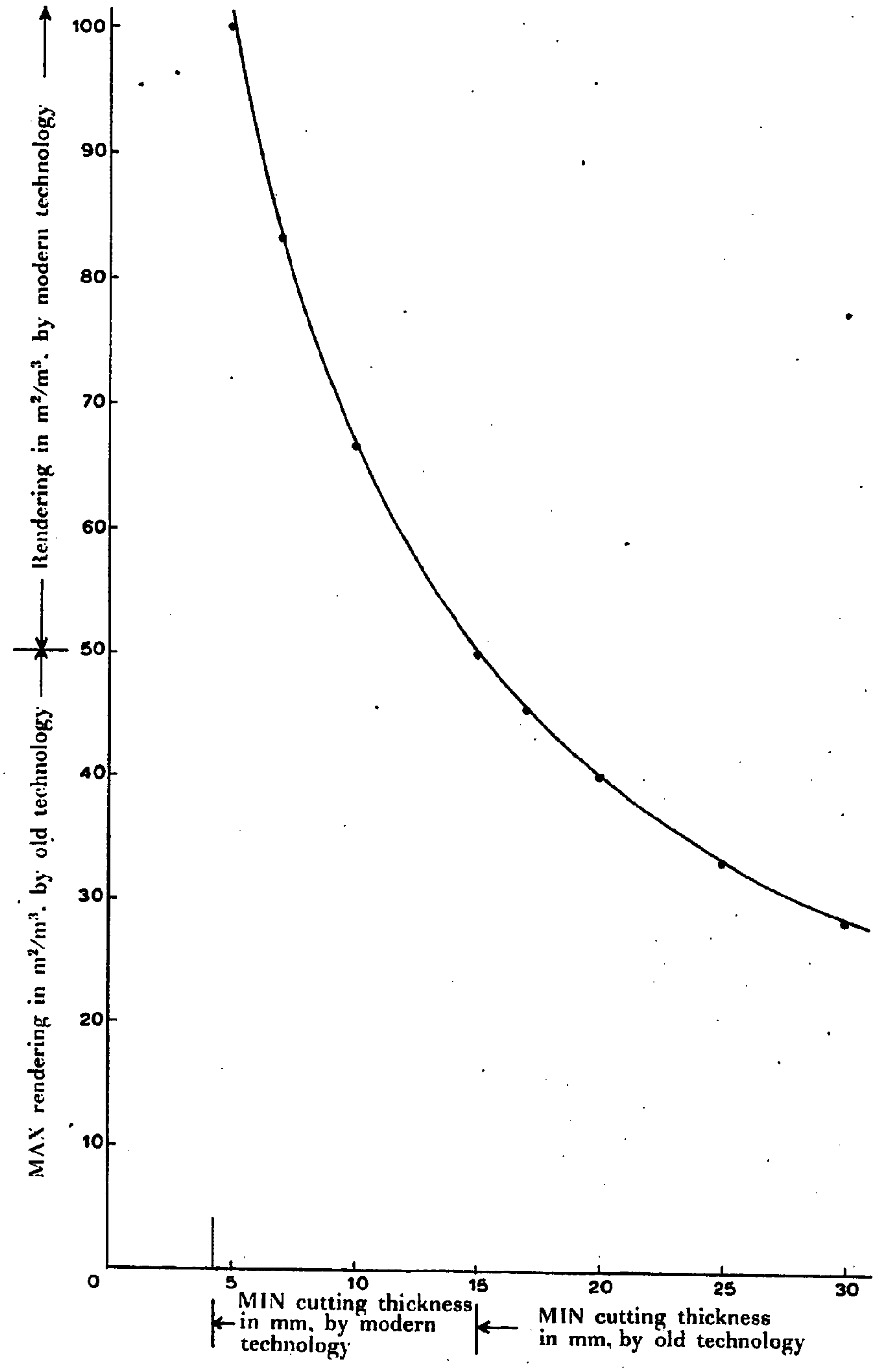

100
90
80
70
60
50
40
30
20
10
0
5
10
15
20
25
30
MAX rendering in m²/m³. by old technology
Rendering in m²/m³. by modern technology
MIN cutting thickness in mm. by modern technology
MIN cutting thickness in mm. by old technology

FIG. 15